NASA Field Center Governance: An examination of NASA's funding – mission mismatch, organizational rigidity, and the proposed solution of transitioning field centers to the Federally Funded Research and Development Center (FFRDC) model

Research Thesis

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By
Colin Grant Edwards

The Ohio State University
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Project Advisor: Dr. John Horack, Professor and Neil A. Armstrong Chair
John Glenn College of Public Affairs
Senior Associate Dean of Engineering
Mechanical and Aerospace Engineering
College of Engineering

Introduction

The mention of “NASA” evokes vivid images of rockets, satellites, moon landers, and space shuttles. These images are indeed ingrained in the imaginations of all Americans and many others around the world. The accomplishments of NASA have provided dramatic stories about the triumphs of human ingenuity and perseverance in accomplishing lofty and difficult goals. The most memorable NASA programs, such as the *Mercury* and *Apollo* missions, resulted in sending some of the first humans into space, enabling the first humans to set foot on the moon, and establishing the U.S. as the preeminent spacefaring nation. These programs were initiated during the youth of the Agency when international competition with the Soviets was at its height and was funded at unprecedented levels which have not been seen since.

NASA’s scope and mission portfolio have grown further since its inception in 1958. NASA now includes directorates tasked with managing decisions on programmatic investments and guiding field center operations (NASA, 2018a). The current mission directorates are aeronautics research, human exploration and operations, science and space technology, and mission support. These operations include eighty-five operating science missions, four programs in the Aeronautics Research Mission Directorate (ARMD), and fourteen programs in the Space Technology Mission Directorate (STMD). Missions and projects range from robotic and human spaceflight, satellites for Earth and astronomical observation, satellites for communications and other science, and nearly 20 years of continuous human occupation of low Earth orbit (LEO) on board the International Space Station (ISS). While NASA’s original purpose of beating the Soviets in space exploration has long been accomplished, the Agency’s utilization has not diminished.

Problem Statement

This paper seeks to identify the budgetary and structural changes in the Agency and changes in the political environment that highlight the development of a misalignment between these variables and the Agency's current mission and purpose. NASA's missions and strategic goals have expanded since the *Apollo* era. However, its budget has substantially decreased in real dollars and as a percent of federal expenditures. The alignment of presidential and congressional vision is also largely diminished. Finally, the Agency's infrastructure and organizational structure remain essentially the same as it was 50 years ago.

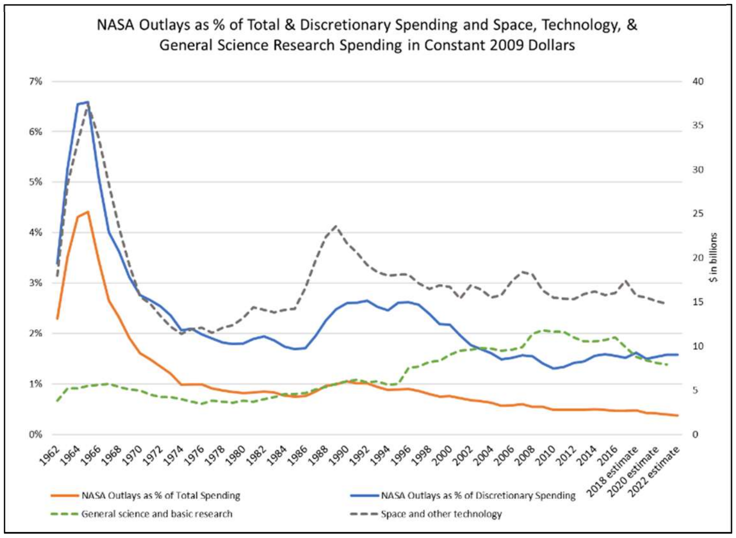
Highlighting this disconnect will proceed through an examination of 1) the Agency's budget decline; 2) historical changes in its organizational model, highlighting the rigidity of NASA's management structure; 3) a discussion of the changes in political discourse concerning the Agency and the competing priorities of political parties and branches of government; and 4) an analysis of NASA stakeholders' values and objectives, and each group's power to and interest in determining NASA's organizational structure.

This paper will then explore one of many potential solutions to some of NASA's problems that periodically crops up in executive-level discussions of NASA's performance; transitioning NASA field centers to a Federally Funded Research and Development Center (FFRDC) model. This exploration will begin by defining, providing the history and genesis of, and the legal basis for FFRDCs. Following, is an examination of variations in the FFRDC model, possible variations of implementation, an analysis of the advantages and disadvantages of converting field centers to FFRDCs, and an examination of the barriers to implementation. A summary and final recommendation will then be provided based on this comprehensive analysis.

Budget Analysis

In stark contrast to the continued growth and expanding mission portfolios of the Agency's mission directorates, NASA's overall budget has sharply declined since the *Apollo* era.

Figure 1

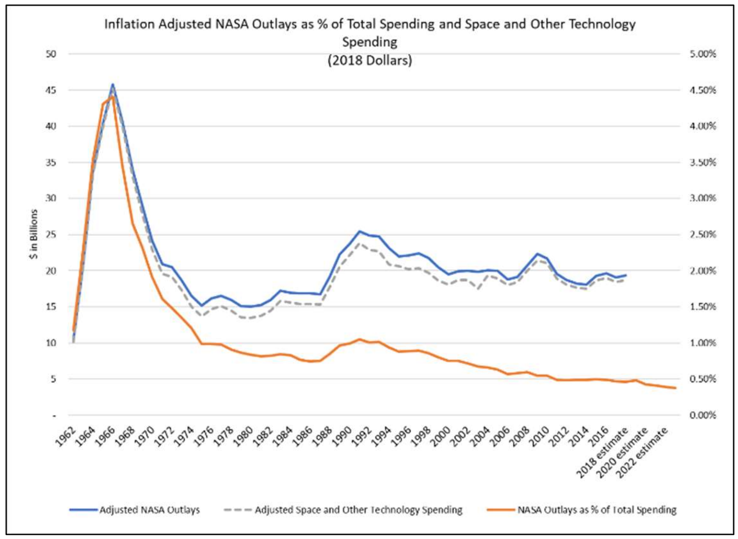


Source: OMB Historical Budget Tables

Figure 1 shows the historical NASA budget since its inception. It depicts NASA outlays as a percentage of both discretionary (blue) and total government spending (orange) in solid lines mapped to the left axis. *Figure 1* also shows the government's "General science and basic research" (green) and "Space and other technology" (gray) categorical spending in constant 2009 dollars in dotted lines mapped to the right axis. Clearly, as the agency emerged and grew, its budget ballooned to its greatest point of 4.41% of total U.S. spending and 6.58% of discretionary spending in 1966. This rise and peak in spending coincided with the prioritization of the *Apollo* program in 1961. As the infrastructure and capabilities were developed and matured, spending began to drop. Between the 1966 budget peak and the time of the first moon landing in 1969, NASA's budget had been reduced by nearly 40%. As a percentage of total spending, NASA's budget has remained relatively stable since 1974, with a small rise in the late 1980s through the late 1990s and a gradual decline since. Although NASA's budgetary changes are more pronounced when measured as a percentage of discretionary spending, the budget trend remains essentially constant. The rises in NASA's budget almost always correspond to increases in the "space and other technology" spending category while spending on "general science and basic research" appears to have no effect on NASA's budget.

However, as more clearly seen in *Figure 2*, there is a pronounced and prolonged decline in NASA's share of total spending compared to its relatively constant budget. While NASA outlays as adjusted to 2018 dollars follows the trend of adjusted "space and other technology" discretionary spending and has fluctuated around $20 billion annually since the turn of the millennium, NASA's share of total spending has declined by nearly 50% over the same period and by 89% since 1966.

Figure 2



Source: OMB Historical Budget Tables, Bureau of Labor Statistics Historical CPI Tables

One may observe that given NASA's budget has remained relatively constant, the drop in its share of total spending is a function of an increase in total government spending. This observation is indeed true. As shown in *Figure 3* in Appendix A, increases in the Departments of Health and Human Services, Treasury, and the Social Security Administration primarily account for the increase in total spending. These three agencies accounted for nearly 65% of the federal budget as of 2017. Approximately 80% of total government spending is contained in four accounts when including Department of Defense Military Programs which is currently nearly 15% of the total budget and has grown by 40% over the same period.

The growth in these large accounts has driven down the budget share of approximately two-thirds of the smaller departments, while the other third has increased its share of the budget. However, of the departments that have experienced decreases, NASA has seen one of the greatest decreases of 89%. Excluding the General Services Administration (GSA) and Small Business Administration (SBA) which have been recently producing revenues, the average drop in budget share is approximately 45%; nearly half of NASA's decrease. Furthermore, since 1966, all 32 government accounts have increased in constant 2018 dollars except for five; The Corps of Engineers – Civil Works, GSA, SBA, International Assistance Programs, and NASA. Of these five accounts, NASA has seen the most pronounced dollar decrease when excluding the revenue-producing SBA and GSA.

NASA's flat budget, the expansion of the Agency's portfolio, the increase in mission costs, and the need to upgrade its aging infrastructure has created a situation wherein NASA cannot execute a robust, balanced aeronautics and space program (Committee on NASA's Strategic Direction, 2012). While the scope of its work has increased, its budget has remained relatively constant since its dramatic decline between 1966 and 1974, and its share of government spending has decreased while most other federal budgets have experienced continuous budget growth. Many high-priority science missions and projects, as determined by the National Academies' Decadal Survey, would require an increase in budget to complete. While the Decadal Survey provides its own prioritization scheme for science missions acknowledging the historical and future budget constraints faced by NASA (National Academy of Sciences, 2011), Congress and Presidential Administrations continue to press NASA to achieve the most highly prioritized science missions while simultaneously prioritizing human spaceflight. In order to fulfil NASA's purpose of enabling the U.S. to lead the way in space exploration, stable funding is required (Whitson, 2019).

There are many other problems facing NASA beyond budgetary constraints. These include a lack of substantive change in the Agency's organizational structure, changing political environments, and ambiguity and disagreement over the Agency's purpose. Despite these challenges, which will be discussed in the following sections, the conclusion clearly emerges that since the days of *Apollo*, NASA has been deprioritized and asked to do more with less, creating a visible disconnect between the Agency's expected performance and its ability to meet these expectations.

Organizational Structure

NASA's organizational structure and governance model has not substantially changed since the late 1960's. Historically, NASA has been a decentralized organization giving broad freedom to its ten field centers and their project managers. The level of freedom enjoyed by managers is a condition of the Agency's dynamic mission (NASA Office of Management, 1985). In the 148 organizational charts published (not including published drafts) since NASA's founding, there have been frequent changes at the Administrator and Associate Administrator level, with dozens of staff offices being created, removed, or relocated within other offices. These changes often reflect shifts in the philosophies of management, oversight, and interagency cooperation and communication functions. NASA's foundational legislation, the Space Act of 1958, endowed the Administrator with the ultimate "authority and control over all personnel and activities" and has thus subjected the Agency's organizational structure to changes with each successive Administrator as they develop their management styles. These frequent changes most often occur above the mission directorate level and attempt to optimize administrative functions, eliminate inefficiencies in communication and authority, and reduce redundancies. Occasionally, disasters provide the impetus for similar organizational changes. The Agency's response to the *Challenger* accident included a reorganization meant to strengthen program managers' roles in decision making and the creation of a new Office of Safety, Reliability, and Quality Assurance (Donahue & O'Leary, 2012).

At the programmatic and functional level, however, the organization has seen two primary iterations based on field center reporting structures. Field centers have historically reported directly to the Office of the Administrator, or to mission directorates. The issue of determining to whom the field centers should report has posed a continuous organization challenge for the Agency. Rationale for field centers to report to mission directorates is limited by the degree to which each center's project activities can be closely identified with a single program office (NASA Office of Management, 1985). However, confusion and unnecessary redundancies may exist under this paradigm when a field office's activities are more evenly dispersed across programs with different objectives.

The alternative of field centers reporting to mission directorates is to directly report to the Office of the Administrator. While field centers primarily reported to mission directorates during the 1960's, this paradigm changed in 1974 shortly after the *Apollo* program came to a close. This structure released field center managers from program Associate Administrators' control over institutional and program management (NASA Office of Management, 1985). In

1982 as the Space Shuttle program grew out of its infancy, this structure was again reversed, and field centers once more reported to the mission directorates for which they performed most of their work. This structure endured until 2006 with only a few iterations. For example, an Office of the Associate Administrator for Space Station was established in 1984 and removed in 1990. Field centers generally reported to the same mission directorate, with a few minor changes such as the bifurcation of the Science mission directorate into Earth and Space Sciences. In this split, the Jet Propulsion Laboratory (JPL) was organized under Space Science and Goddard Space Flight Center was organized under Earth Sciences although each center continued to work on missions for both categories. In 2006, the paradigm shifted back to field centers reporting directly to the Administrator and has since remained unchanged.

The field centers themselves have not undergone any substantial organizational changes despite undergoing many small-scale changes. Center directors' roles have not substantively changed other than in their collaboration and cooperation functions with mission directorates, program offices, and project managers. Field centers have been organized within the hierarchy in only the two ways discussed in the previous paragraphs. This organizational analysis highlights NASA's inflexibility and apparent lack of innovation as it relates to field center management.

NASA's institutional rigidity may have negative consequences. For example, the U.S. may be losing its competitive advantage in space as more countries develop space capabilities. "Since many [countries developing space capabilities] are creating their space institutions from the ground up, they are not locked into the same legacy institutional structures as in historically spacefaring countries such as the United States" (Lal, 2018). As new spacefaring nations emerge, they can build their agencies based on modern trends in governance and the global space economy, whereas NASA is structured around the 1960's Cold War environment. While the commercial resupply and crew programs have taught NASA how to effectively work with the commercial sector and manage public-private partnerships (Heracleous, Terrier, & Gonzales, 2018), there is no evidence that NASA's organizational structure has been an enabling feature of this learning.

Political Environment

The NASA administrator is appointed by the President and ratified by the Senate. NASA's budget and some programmatic changes also require legislative approval. Congressional and Presidential priorities are often misaligned. Competing priorities and varied levels of authority creates an environment of constant uncertainty for the Agency. Presidential prerogatives are expected to be carried out by the Administrator who is subject to congressional oversight. Furthermore, legislators hold the power of the purse and all NASA appropriations must be enacted annually by Congress. The President's budget request forms the basis of each budget cycle but is never passed without Congressional adjustments. Although the President may veto any bill, the current system of passing large and comprehensive omnibus appropriations bills reduces the likelihood of such an event (American Council on Education, n.d.). Unlike 38 state governors, the President does not have any form of line-item veto power, as the temporary powers given in 1997 were invalidated by the Supreme Court the next year (Lee, Johnson, & Joyce, 2013).

The appropriations cycle therefore subjects NASA to potential changes in short-term spending decisions on long-term projects. While government shutdowns caused by failure to pass a budget have been historically rare until the last decade, continuing resolutions still prohibit the required phasing of funds to match the development cycles of NASA's many projects. Programs originating at the White House may not receive the support and funding they require from Congress to be successful. For example, President George W. Bush announced the *Constellation* program which aimed to send astronauts back to the moon and eventually on to Mars. The program would develop a new crew capsule and launch system, named *Orion* and *Ares*, respectively. This program was consistently underfunded, fell behind schedule, and was eventually discontinued by President Barack Obama in 2010 (Stromberg, 2015).

A congruent launch vehicle and space transportation project, the Commercial Cargo and Crew Programs, were initiated in 2006. The initiatives, which were designed to hold down costs and appease free-market Republicans, also continually faced political resistance (King, 2013). The NASA Authorization Act of 2010 mandated and authorized NASA's *Space Launch System* (*SLS*) utilizing heritage technology and studies from the *Constellation* program (Creech, 2014). Rejection of President Obama's policy change towards a solely private launch and crew system was based on Congress' alternate opinion regarding the necessity of a government-owned launch vehicle. Considering the $9 billion already spent on the *Constellation* program, and the possibility of an estimated $2.5 billion in contract termination fees, Congress determined that the displacement of human capital, skills, and the disruption of the nation's industrial base resulting from the cancellation were unacceptable (Senate Committee on Commerce, Science, and Transportation, 2010).

Although Congress mandated the *SLS*, it is still subject to the appropriations process and the changes in political priorities that accompany discretionary spending. Critics have long called the *SLS* a "rocket to nowhere" and criticize it as a government jobs program rather than a real solution to advancing U.S. space capabilities. Having suffered from constant budget overruns and delayed deadlines, the latest delays have caused the administration to consider using commercial rockets instead to begin testing the *Orion* crew capsule. (Thompson, 2019). The President's FY2020 budget proposal suggests cutting funding for *SLS* by $375 million compared to 2019 and to defer work on the rocket's Block 1B upgrade. This proposed cut would have effects external to the project, including impairing the in-process production of a second mobile launch platform. Program managers for the mobile launch platform intend to have conversations with Congress regarding this threat and plan to continue with FY2019 funds (Foust, 2019). However, uncertainty in the project's future will remain until the final appropriations bill is enacted. Even so, that certainty will only last until the following year's budget cycle begins.

Other recent projects have faced similar threats of discontinuation. In its FY2018 budget, the administration slated the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission for cancellation. Although Congress ultimately decided to continue its funding, there are real effects associated with the uncertainty. Prolonged budget uncertainty not only causes psychological and motivational stress for project staff, but also can lead to difficulty committing to long-term planning, manifest as inabilities to release project competitions (Foust, 2018), delays in ordering of lead-time components, and eventually project delays.

There are some who believe that NASA is unnecessary and that its budget could be better spent elsewhere. However, NASA has established legacy infrastructure accompanied by a low priority in its divestiture (NASA, 2018a), provides thousands of civil service and contractor jobs, enables the creation of thousands of small business jobs annually (NASA, 2017a), and has become so engrained in the conscious of the American public that politicians are unlikely to terminate the Agency. The purpose of NASA is simultaneously ambiguous and specific enough that general political agreement can often be reached. The Agency produces tangible science such as the Mars rovers, the Hubble Space Telescope, the International Space Station National Lab, creates opportunities for education, and also promotes aspirational goals such as U.S. leadership and deep space exploration. This wide scope allows enough room for most legislators to identify value in the Agency, even if the specific mission and project manifestations of that value are contested.

NASA Stakeholder Analysis

In order to better assess the efficacy of converting NASA field centers to an FFRDC model, it is necessary to understand the network of NASA stakeholders, each group's values and objectives, and their roles and abilities in shaping the Agency's structure. This section will outline the stakeholders, identify their values and objectives, and discuss each group's interest in and power to shape the governance structure of the Agency.

The Power vs Interest Matrix was developed by Colin Eden and Fran Ackermann and categorizes stakeholders into four groups based upon their interest in the strategic activity initiated by an organization and their power to influence the achievement of the strategic activity. Stakeholders with high interest and power are labeled "Players" and must be carefully considered as they can support or sabotage a strategy. Those with high power and low interest are labeled “Context Setters” and must be carefully managed as they can be moved into the Player category and sabotage or support strategies. Actors with low power and high interest are labeled “Subjects” and are often the most affected by strategies. This group’s interests must be considered although their buy-in is not necessarily required for successful strategy deployment. Those with low power and low interest are labeled “Crowd” and can largely be ignored in strategy deployment considerations (Eden & Ackermann, 1998). This Power vs Interest analysis is represented graphically in *Figure 4* attached in Appendix B.

Congress:

The group of stakeholders with the ultimate power in determining NASA’s future is Congress. This group controls the appropriations process, must confirm political appointments, and approves certain programmatic changes. Legislators have a large range of values and objectives. However, as most are primarily concerned with maintaining their positions and winning reelections, they act in a manner that aligns with their understanding of the majority of their constituents’ political values.

Regarding FFRDCs, Congressional legislation is not expressly required to establish a new FFRDC, but the sponsoring agency must submit to Congress a report describing the purpose, mission, and general scope of the center (FAR, 35.017-7(a)). Furthermore, the funding for an FFRDC must be appropriated by Congress which can also establish, terminate, or alter an FFRDC through legislation. Members of Congress who do not serve on a NASA- related committee or do not have NASA facilities in their jurisdictions are categorized in the “crowd” considering their relatively low level of individual power and interest. These members are likely to vote on legislation according to the direction of the relevant committees and their political party's leadership expectations.

Within Congress however, there are multiple levels of authority and power. While legislation requires a vote on the floor of both the Senate and House of Representatives to become law, demonstrating the proportional power of each member in determining NASA's future, every bill must first clear the appropriate committees. Once a bill is introduced, it is referred to the committee under which its contents are most aligned. If another committee claims to have jurisdiction over a part of the bill, there are two paths that can be taken. First, the primary committee can review and suggest amendments before passing it along to the next committee to do the same. Once each committee has voted to recommend the bill for a vote, it can then move to the floor for final consideration. Second, the primary committee can ask for a waiver from the other committee. If the waiver is granted, the primary committee will process the bill alone. If the waiver is not granted, the first process must be followed.

Committees hold significant power since they determine which bills will be given consideration. They are also where other Congressional business is conducted, including oversight and investigation duties. Appropriations bills and budget requests are first evaluated in Committees. Appropriations for FFRDC funding must be secured through this process. Even if an agency had existing funding flexible enough to independently establish an FFRDC, doing so without Congressional approval would likely solicit oversight and investigation, and subject the agency to harsh scrutiny come the next budget cycle.

The Congressional organizations responsible for NASA are the 1) Senate Committee on Commerce, Science, and Transportation; 2) The Senate Subcommittee on Aviation and Space;

3) The House Committee on Science, Space, and Technology; and 4) The House Subcommittee on Space and Aeronautics. A list of each committee's leadership and full subcommittee membership is listed in *Figure 4*.

Many of the individuals on these committees and subcommittees have NASA centers or facilities in their districts or states. Given their positions, these individual members of Congress hold more power over and interest in NASA's governance than other members. According to non-attributional interviews with legislative staff, members of Congress with a NASA center or facility in their district or state are sensitive to the economic implications of adjusting the Agency's structure. Legislators campaign on job creation and protection and federal jobs are difficult to remove. Turning NASA centers over to private entities with greater flexibility in determining the size of its workforce puts considerable pressure on legislators' claims to job protection.

This group is organized in the Power vs Interest Matrix in two categories. First, the Senate Committee on Commerce, Science, and Transportation and the House Committee on Science, Space, and Technology are categorized in the "context setters" quadrant. This group is highly transient and can easily move into the "players" segment when it comes time to vote. Otherwise, the concerns and obligations of these bodies are widely varied and are frequently not focused on NASA-specific business. Second, given both their interest in and power over NASA, the Senate Subcommittee on Aviation and Space and the House Subcommittee on Space and Aeronautics are grouped in the "players" category and should be carefully considered in attempting to change NASA's governance models. The buy-in and support from this group is essential in any attempt to convert a NASA field center to an FFRDC. To accomplish such a goal would require a strong case be made to these bodies for how the economic advantages would overcome the impact from a loss of federal jobs. A more detailed discussion on the barriers to implementing FFRDC conversions will explore this topic further.

Executive Branch:

The executive branch is segmented into five relevant groups external to NASA. First, the President of the United States, as the chief executive, has considerable power in determining the structure of NASA which is an executive branch organization. The President appoints the Administrator and is the ultimate director of strategy, policy, and budget proposals. While the President must rely on Congress for leadership and budgetary approval, the President has considerable power in determining the policy direction through management pressures and executive order. For example, President Trump's Space Policy Directive 1 (SPD1) determined the strategic direction for NASA regarding space exploration. SPD1 directed NASA to focus on building partnerships with commercial firms and international partners to focus on making a sustained return to the moon and then on to Mars. While this document directs NASA to focus its efforts on returning to the moon, it only carries the authority to affect change within the constraints of existing law and appropriations. As such, the President is categorized as a "context setter" as the President's attention and interest is frequently focused away from NASA. On occasion the President can move into the "players" quadrant and exert their control over NASA.

To a lesser extent, the Vice President of the United States carries similar authorities as the President. The Vice President is currently the Head of the National Space Council which was reinstituted in 2017 by Presidential executive order. This organization is tasked with establishing the nation's space policies and incorporates civil, military, and commercial space interests (Berger, 2017). Serving in a research and advisory role, the Vice President and the National Space Council do not have executive power over NASA, but rather, influence over the President's decision-making and policy formulation. The National Space Council is staffed by the head executives of departments and offices whose endeavors include space operation as well as a civilian executive secretary. The organization received criticism in the past, especially from NASA, for adding an additional layer of bureaucracy to an already encumbered civil service. However, this opinion only strengthens the observation that the National Space Council exerts considerable influence over NASA (Kaplan, 2017).

The Vice President and the National Space Council have several values and objectives. The Vice President aims to support the President in advancing the chosen agenda and steers the National Space Council in this direction. Being staffed by head executives from many offices, the National Space Council has many internally competing values and objectives. As a whole, the Council works towards increasing the effectiveness and efficiency of space operations and programs within its constituent offices. The Council pursues objectives aimed at increasing commercial competitiveness, military dominance, and supremacy in space exploration and science. This group is placed in the "players" category given their interest in and ability to influence NASA policy. However, considering the conflicting interests within the National Space Council and its ability to only influence others who can directly determine NASA's policies, they are situated at the low end of the "players" power continuum.

The Office of Science and Technology Policy (OSTP) is situated in the Executive Office of the President and serves a similar role to the National Space Council. The OSTP has been in continuous existence since 1976, whereas the National Space Council was founded during the Eisenhower Administration, discontinued by President Clinton, and reestablished by President Trump (Kaplan, 2017). OSTP is tasked with providing the President "with advice on the scientific, engineering, and technological aspects of the economy, national security, homeland security, health, foreign relations, the environment, and the technological recovery and use of resources, among other topics" (Office of Science and Technology Policy, n.d.). The values and objectives of OSTP are also similar to the National Space Council, except that being an independent office it does not have the conflicts of interest that the National Space Council may have from being composed of leadership from other executive offices. OSTP is singularly dedicated to providing policy direction to the President based on its independent research and analyses. Although OSTP has a great deal of interest in NASA and the possibility of converting field centers to an FFRDC, it has a weaker line of communication to the President without the Vice President's leadership role. It also has no direct power over NASA, its organizational structure, or field center governance models; only the power to influence Presidential policy regarding such issues. Thus, it is placed in the "subjects" category, although towards the top of the power continuum.

The Office of Management and Budget (OMB) is the final executive branch organization with vested interest in and power over NASA. Like OSTP and the National Space Council, OMB has no direct power over NASA's organizational structure or field center governance models. However, as the office is the executive branch's primary organization responsible for government budgetary formation and fiscal evaluation and oversight, OMB has significant influence with both the President and other executive agencies. Most agencies are required to submit substantive policy and regulatory proposals to OMB for review as to their compliance with Presidential priorities and goals (Haeder & Yackee, 2015). While OMB does not have any formal authority to change agency policy, compliance with OMB suggestions is standard practice (Rosenbloom, 2003). While this review process tends to set the standards by which agencies form internal policies and regulations, OMB does not carry the same weight regarding new ideas.

For example, OMB recently conducted an independent review of the government and provided recommendations for reform and reorganization to reduce waste and increase efficiency in the executive branch. In the OMB evaluation of NASA, it recommends that NASA increase its use of FFRDCs by converting field centers to the model (Office of Management and Budget, 2018). While this recommendation has been seriously considered, and a response study and report provided by NASA, the authority to make such changes does not lie solely with OMB, NASA, or the President. Regardless, OMB can exert considerable pressure on those responsible for setting NASA policy. Thus, OMB is categorized in the "players" category, although towards the lower ends of the power continuum since its power is derived only through the ability to influence others in the executive branch.

NASA:

While NASA is an executive agency, as the Agency targeted for structural changes, an analysis of the Agency's internal stakeholders is required. The most prominent internal stakeholder is the Administrator. According to FAR section 35.017-2(j), establishing an FFRDC requires the approval of the sponsoring agency's head. Therefore, without the consent and backing of the Administrator, no proposal to convert a NASA field center to an FFRDC model can proceed. The Administrator's interest in such a decision is equal to their power over it. As the head of NASA, the Administrator's goals and priorities are to run the Agency effectively and efficiently, maintain mission achievement across all of NASA's administrative and project functions, and enact the policy priorities of the President. If converting a field center to an FFRDC model could assist the Administrator in any of these functions without resulting in other negative impacts, the Administrator could be compelled to endorse such a proposal. As the only "player" in NASA's internal structure, and a key component to initiating a change in the governance model for a field center, the Administrator's buy-in and support is critical.

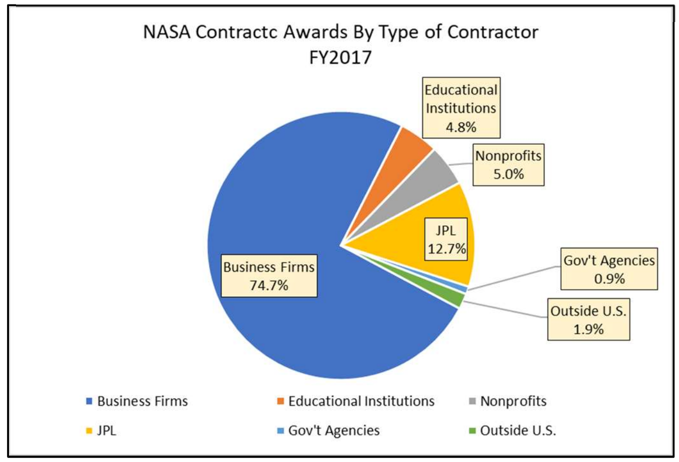
Other internal stakeholders include Mission Directorate Associate Administrators, Field Center Directors and staff, Program and Project managers, and all the rest of NASA staff. These stakeholders are all categorized as "subjects" as they have a high interest in the decision outcome but have relatively little power over influencing the decision itself. It is assumed that Congress, OMB, and the NASA Administrator would consider this group's values and priorities but doing so is not required in moving forward with converting field centers to an FFRDC model.

Private Sector:

Public sector actors are not the only NASA stakeholders. In the private sector, federal contractors, FFRDC and University Affiliated Research Center (UARC) operators, academia, think tanks, media, and the general public are all affected by NASA's actions. Contractors have an enormous opportunity to profit from the Agency which had procurement obligations (excluding grants) in 2017 of $18.5 billion. As depicted in *Figure 5* below and *Table 1* attached in Appendix C, business firms accounted for more than $13.8 billion in contract award obligations.

Educational institutions, nonprofit organizations, and other governmental organizations also received hundreds of millions of dollars in NASA contract awards. *Table 1* and *Figure 5* also relate that the Jet Propulsion Laboratory (JPL), NASA's only operating FFRDC, was the recipient of more than $2.3 billion. Thus, any organization that might intend to compete for a contract to manage a new FFRDC at NASA has a base from which to gauge the magnitude of such an operation. While nonprofit organizations, JPL, and other governmental agencies are not primarily concerned with creating shareholder value as are their private firm counterparts, every stakeholder values the productive capacity they gain from NASA contracts.

Figure 5



Notwithstanding the monetary gains available to these stakeholders and the interest it creates in working with NASA, these organizations have no direct power over decisions regarding the Agency's organizational structure. However, private firms have some power in their ability to lobby Congress to act in their favor. The total 2018 lobbying expenditures in the defense and aerospace sector was over $65 million. The top three individual company contributors were Boeing, Northrop Grumman, and Lockheed Martin (Center for Responsive Politics, 2019). Each of these companies are in the top ten recipients of NASA contract awards; Northrop Grumman is tenth and Boeing and Lockheed Martin are respectively the two highest (NASA, 2017b). Despite private industry's lobbying influence over some members of Congress, firms do not have the direct power to determine NASA's organizational structure and governance model and are therefore categorized as “subjects” whose interests and inputs should be considered although it is not necessary.

FFRDC Conversion as a Solution

Converting NASA field centers to an FFRDC model has occasionally been recommended as a solution to perceived inefficiencies, a lack of innovation, and a lack of agility in responding to policy and economic changes. In 2004, the President’s Commission on Implementation of United States Space Exploration Policy, known as the “Aldridge Commission”, concluded that NASA centers “are not appropriately configured to carry out the nation’s exploration vision.” Based on the Commission’s assessment of the inefficient duplication of processes, rigid personnel policies, and an insufficient priority on innovation it recommended that all NASA centers be transitioned through an open and competitive process to become FFRDCs (2004). In response, the Agency established NASA’s Organizational Model Evaluation Team. Based on its report, rather than increasing its use of non-governmental organizations, NASA pursued the approach of encouraging “healthy centers” by addressing infrastructure concerns and working more closely with the private sector (NASA, 2018b).

More recently, OMB issued the recommendation that NASA increase its use of FFRDCs to meet the requirements of SPD1. Citing the Aldridge Commission and the new President’s National Space Strategy, OMB recommended that NASA initiate a new evaluation of the use of FFRDCs to bolster NASA’s agility and realize the Administration’s goal of returning American astronauts to the moon. Specifically, OMB asserts that FFRDCs may offer increased flexibility in workforce management. By offering more competitive compensation and a more flexible recruiting process, it is assumed that FFRDCs may be better situated to attract and retain top scientific and technical talent and respond more rapidly to changing R&D needs than is possible with a civil workforce (OMB, 2018). As OMB does not have direct control over NASA, the report simply suggested that NASA conduct a study exploring the feasibility of the recommendation to inform future White House budgets, policy plans, and proposals. NASA completed its study and submitted its findings to the White House on August 31, 2018. This and other reports' findings will be discussed later in this paper.

FFRDC Primer – Genesis, History, & Defining Characteristics

FFRDCs were established during the Second World War as a means of mobilizing the nation's scientific and engineering talent to address specific and sustained challenges of war-time national security (Hruby, et al., 2011; Howieson, Clavin, & Sedenberg, 2013). Technologies such as the proximity fuse, advanced radar and sonar, and the atomic bomb were developed at these early centers (Government Accountability Office, 2008). Although operating with the name "Federal Contract Research Centers", these organizations expressed the same characteristics and operated in the same manner as modern FFRDCs (Gallo, 2016). This model was conceived in 1942 with the Applied Physics Laboratory (APL) sponsored by the Office of Scientific Research and Development.

After the war, the need for sustained development of independent and technical national security capabilities remained. FFRDCs were formally established under Federal Acquisition Regulation 35.017, and in 1947 the U.S. Air Force established RAND as the first official FFRDC (MITRE, 2015). Developments in defense systems, computing, and nuclear weapons over the following decades allowed FFRDCs to flourish. As the popularity of FFRDCs grew, federal R&D funding for them increased from 0.4% in 1960 to 1.2% by 1970, followed by a sharp change in Congressional, academic, military, and industrial perspectives. In response to a percieved lack of Congressional oversight over FFRDCs, their control over policy, their unfair advantage in obtaining R&D work, and sponsor-biased R&D the number of FFRDCs quickly receeded from a peak of 74 in 1969 (Hruby, et al., 2011; MITRE, 2015). Department of Defense-sponsored FFRDCs fell from 39 to eight by 1976, and APL was transitioned to a University Affiliated Research Center (UARC) (Hruby, et al., 2011). Despite this precipitous drop in their use, FFRDCs evolved with the shifting perspectives and needs of government R&D and continue to be utilized (MITRE, 2015). As of 2018, eleven agencies sponsored 43 FFRDCs. The Department of Energy and Department of Defense most utilize FFRDCs, sponsoring sixteen and eleven, respectively (National Science Foundation, 2018).

FAR 35.107 dictates the characteristics required of FFRDCs. They must 1) address a specific and long-term R&D need that connot be met by either the federal government or private industry, 2) work objectively in the public interest and maintain full disclosure with sponsoring agencies, 3) operate as an independent organization or an identifiably separate unit of a parent organization, 4) maintain familiarity with the needs of sponsoring agencies and sustain a long-term relationship that attracts high quality personnel, and 5) preserve technical and scientific expertise in their mandated fields. Furthermore, to establish an FFRDC, there must be sufficient government controls to ensure reasonable costs are being charged for services and expertise to evaluate its work. FAR also establishes that an FFRDC may complete work for organizations other than its sponsor under the conditions that such work falls within the scope and purpose of the FFRDC and is approved by the sponsor who will ensure FFRDC compliance.

Upholding these characteristics is necessary for FFRDCs to achieve long-term success, not just because they are federally mandated (Hruby, et al., 2011), but also because it allows them to adapt to the changing needs and expectations of federal R&D. FFRDCs are meant to address R&D needs that cannot be met by either the government or private industry alone, thus representing a unique strategic relationship of sole-source funding in federal contracting. This strategic relationship is defined by two overarching characteristics; 1) special access to government resources and; 2)information and the longevity of the partnership.

This special relationship and the use of non-competitive contracting has drawn criticism from industry and Congress (Gallo, 2016). Others argue that the sole-source contracting and lack of competition allows FFRDCs to maintain objectivity and alignment with their sponsoring agencies (MITRE, 2015). Budgetary pressures of the recent decade have also put pressure on the government and FFRDCs, causing some FFRDCs to expand and diversify their program portfolios. Industry and academic providers of federal R&D, feeling the same budgetary pressures, have attempted to increase their competition with FFRDCs (Hruby, et al., 2011). As the capabilities and competencies of the private sector have become more sophisticated, the claim that FFRDCs have been given an unfair and unnecessary advantage over private R&D firms has grown stronger. This criticism asserts that FFRDCs have deviated from their original intent of providing R&D that can not otherwise be provided (Professional Services Council, 2012). However, the continued need for specialized R&D contracting, the long-term relationships between FFRDCs and their sponsoring agencies, and special access to government data that is otherwise unavailable to R&D contractors have proven to be powerful assets keeping FFRDCs relevant.

FFRDC and Federal R&D Institution Variations

While the FFRDC model is a legislated structure with defined characteristics and rules governing their formation, oversight, and continuation, there exists diversity in their missions and operating models (Hruby, et al., 2011). DOD developed, and the National Science Foundation maintains, a classification system for FFRDCs. They are classified by their activity types and include R&D laboratories that maintain long-term competencies, study and analysis centers that provide independent and objective analysis and advice to agencies, and system and engineering and integration centers that provide complex systems engineering capabilities (U.S. Department of Defense, 2011; Congressional Research Service, 2016). This classification system allows for a broad array of R&D activities to be conducted under the FFRDC model. As of March of 2018, there were seven systems engineering and integration centers, ten study and analysis centers, and 26 research and development laboratories.

Like FFRDCs, University Affiliated Research Centers (UARC) are non-profit organizations sponsored by federal agencies to conduct research that neither the public or private sector can provide alone and receive sole-source (non-competitive) federal funding (Howieson, Clavin, & Sedenberg, 2013). UARCs are similarly defined by their long-term relationships with and extensive understanding of their sponsoring agencies, freedom from conflicts of interest, independence and objectivity, access to sensitive agency information, and the agility to appropriately respond to quickly evolving research needs. However, UARCs are not defined by federal law but rather were established and are governed by the DOD UARC Management Plan (U.S. Department of Defense, 2010). UARCs also differ from FFRDCs in that they must be affiliated with a university or college, include education in their mission, and have broader authorities to compete for public and private contracts outside of their duties to their sponsoring agencies (Congressional Research Service, 2016; Hruby, et al., 2011).

There are a few additional research institution models that are utilized for federal R&D. These include private or academic research institutes and private research corporations. While such organizations do receive some federal R&D contracts, they cannot sustain the full capacity of federal research needs. These organizations are funded by private firms, funded through research universities, or a combination of both. Therefore, they are beholden to the profit incentive, special interests, or the research prerogatives of their university affiliates rather than to the public interest. Some of the most influential and innovative research institutes, such as Paul G. Allen's Vulcan Inc. and Allen Institute, and Fred Kavli's brain institutes at Yale, Columbia, and the University of California, have been founded by private finance (Broad, 2014).
These entrepreneurial, and sometimes philanthropic, organizations have proven successful in addressing issues that federal research has failed to target and bolstering basic science research in higher education which fell federally by 30% between 2003 and 2015 (Office of Research Services, n.d.; Science Philanthropy Alliance, 2018). However, they can also find it hard to justify and afford the "pure" and other long-term, agency specific research activities that government owned and operated R&D institutions pursue (Ewalt, 2016).

Variations in Field Center FFRDC Conversion Strategy

Having introduced, characterized, and examined some variations of federal research institutions and FFRDCs, an examination of the possible variations in converting NASA field centers to this model can now be conducted. There are five options to consider: 1) not converting any field centers to FFRDCs or UARCs; 2) converting all field centers to either FFRDCs or UARCs; 3) converting only some field centers to FFRDCs or UARCs; 4) creating new FFRDCs or UARCs and moving some functions and capabilities out of existing field centers to the new organizations; and 5) converting parts of select field centers to FFRDCs or UARCs.

There are several other alternatives to increasing agility such as better leveraging current authorities in human capital and procurement, seeking additional authorities in human capital and procurement, and coordinating with the federal government to establish cross-organizational approaches to managing areas such as information technology R&D and space traffic management (NASA, 2018b). However, these alternatives are outside the scope of this paper and will not be evaluated.

Advantages and Disadvantages of FFRDCs

Advantages:

There are two primary arguments for using FFRDCs over government owned and operated R&D centers. First, there are increased flexibilities and organizational efficiencies associated with the FFRDC model. Being managed and operated by contracted non-profit entities, they have the authorities to expand or reduce their workforce at a comparatively rapid pace. FFRDCs are not constrained by the civil service laws that govern every aspect of the federal workforce. Most of the 3,400 civil service regulations have not changed in 100 years and were enacted to end the spoils system prevalent in 19th century American politics (Risher, 2017). Specifically, the lack of restrictions on hiring and compensation enjoyed by FFRDCs allow for increased flexibility (Kosar, 2011). It is this freedom over hiring, firing, and compensation that allows FFRDCs to more rapidly adjust to changing R&D needs and attract and retain higher caliber talent. As federal R&D needs change, the civil service must adhere to its cumbersome regulations while FFRDCs can terminate, transfer, or relocate workers rapidly. One example offered by multiple (non-attributional) interviewees was that of wind tunnel technicians at NASA's Glenn Research Center. When utilization of these facilities is in lower demand, the Agency must follow strict civil service regulations and cannot remove the technician from their post, creating inefficiency and wasting resources.

Furthermore, inefficient or underperforming federal employees cannot be promptly removed, but must first be enrolled in a Performance Improvement Plan (PIP). The length of the program and the benchmark performance factors the employee must reach are determined collaboratively between management, the employee, human resources, and union representatives. If performance has not improved by the conclusion of the PIP, the manager may then place the employee on probation (U.S. Merit System Protection Board, 2015). If performance still does not improve, the manager may then decide to demote, reassign, or terminate the employee. However, this action requires a six-step process which includes human resources representatives, attorneys, agency management, and union representatives. (Office of Personnel Management, n.d.). Conversely, at an FFRDC, if a researcher is not performing at a certain level, management has the option to promptly terminate their employment (Howieson, et al., 2013). With approximately 98% of NASA's federal workforce categorized as civil servants under Title 5 (NASA, 2018b), adopting new governance models with greater human capital flexibilities could prove very effective in increasing the Agency's agility.

Recruiting and hiring practices are also a burden to NASA's agility and responsiveness to changing economic conditions and R&D needs. While FFRDCs can attract and onboard new employees from ten to 75 days, it takes NASA an average of 109 days to complete the same process (NASA, 2018b). This problem is not specific to NASA but endemic to government owned and operated federal laboratories and R&D institutions. A broad study of federal security laboratories shows that young professionals are not being hired in sufficient numbers to replace aging personnel (Howieson, et al., 2013). Further complicating recruitment efforts, many R&D facilities require that personnel acquire security clearances which can take up to a year. Ensuring efficient hiring capabilities at all experience levels is thus critically important (The Commission to Review the Effectiveness of the National Energy Laboratories, 2015a) to maintaining adequate staffing levels and efficiently performing R&D assignments.

A NASA evaluation recently identified the need to more effectively use existing authorizations over human capital management (NASA, 2018b). By failing to fully and properly utilize the human capital authorities currently available to the Agency, it is allowing inefficiencies to exist. NASA recently established the Business Services Assessment (BSA) process to build an Agency-wide strategic workforce plan, modernize recruiting and hiring, centralize staffing and classification to facilitate consistency across the Agency, and strengthen supervisory accountability (NAC Institutional Committee, 2017; NASA, 2018b). While the Agency believes these adjustments will increase its agility and efficiency, it concedes that additional authorities and workforce innovations would facilitate further improvements.

Partially stemming from this greater workforce flexibility is the second primary argument for using FFRDCs over government owned and operated R&D centers; increased creativity and innovation. Having increased flexibility in hiring practices and compensation has historically enabled FFRDCs to attract higher caliber employees, resulting in greater innovation and preserving the nation's technical base (MITRE, 2015; Hruby, et al., 2011). These higher performing personnel are also afforded greater flexibility in their work responsibilities. That is, FFRDCs provide higher levels of funding to unstructured, independent R&D. Since the general discontinuation of NASA's Center Director's Discretionary Fund, the agency now allocates an average of approximately 2% of its total budget on independent research compared to FFRDCs which expend between 3% and 8% of their budgets on independent R&D (NASA, 2018b). Having to rely on Congressional appropriations to fund each department and many projects, NASA is less capable than FFRDCs in allowing such unstructured and purely innovative work time.

The very purpose and structure of the FFRDC model as a vehicle driving R&D that neither the private sector or government can produce on its own encourages innovation. The goal and purpose of an FFRDC is to develop innovative solutions to problems that would otherwise remain unaddressed. The less restrictive legal structures of FFRDCs enable management to "do whatever is not forbidden to do by law, thus providing the basis for innovation and partnerships" (Kosar, 2011). However, the strength of this freedom is limited by the degree to which the FFRDC builds trust with its sponsoring agency through time-tested and proven ability to deliver (The Commission to Review the Effectiveness of the National Energy Laboratories, 2015b).

Disadvantages:

While FFRDCs provide some critical benefits to their sponsoring agencies, they are not a "silver bullet" that can solve all the problems in federal R&D. FFRDCs provide consequences that can be equally as difficult to bear as their benefits are advantageous. First, higher employee compensation and non-competitive contracting generates higher variable and total costs that are shouldered by the sponsoring agency with diminished cost control. The increases in variable costs result in higher costs for customers (Howieson, Clavin, & Sedenberg, 2013). However, as the customers in these relationships are federal agencies, the high costs are ultimately borne by the taxpayer.

The subject of sole-source FFRDC contracting is a contentious matter with strong arguments on both sides of the issue. As recipients of sole-source (non-competitive) contracts, FFRDCs have strong pricing power over their services and operate without assuming the business risks or costs normally associated with federal R&D contracting (Kosar, 2011). These noncompetitive contracts expose the government to increased risk stemming from its lack of negotiating leverage otherwise available in a competitive environment (Government Accountability Office, 2015). This pricing structure has frequently come under attack by critics of the FFRDC system who view increased competition as the best way to decrease costs and increase quality (Gallo, 2016).

Yet, increased agility is one of the foundational characteristics of FFRDCs. By the Department of Energy's estimates, competing FFRDC contracts takes approximately 18 months and can cost the contracted center between $3 million and $5 million to prepare a bid (2009). This process is substantially time consuming considering the average procurement time of FFRDCs is between 93 and 143 days (NASA, 2018b). If this pattern holds true in competing all FFRDC contracts, one of the primary benefits of an FFRDC is greatly diminished.

Furthermore, using competitive contracting to reduce the costs of FFRDCs runs contrary to one of their foundational characteristics as determined in the FAR; that their work be of such a nature that neither the private or government sectors can alone fulfill the R&D requirements, and thus, is not suitable for competitive bidding. Therefore, it stands to reason that if an FFRDC fulfills the requirements of the FAR, it necessarily cannot be subjected to competitive contracting, and will therefore be more expensive than a government owned and operated R&D center. In this circumstance, supposing the R&D need has been deemed essential, the high costs of operating an FFRDC may be justified. If the majority of a FFRDC's work can be competitively contracted, the center is likely no longer necessary, and the high costs of its operation no longer appropriate.

Absent substantial research about how many FFRDC-awarded contracts could qualify for and the government benefit from increased competitive contracting, an acceptable proxy measure may be the rate at which sole-source FFRDC contracts are protested. A protest may be filed by any interested party with the Government Accountability Office (GAO) over the award or proposed award of any procurement contract by federal agencies. However, subcontracts are not subject to protest (U.S. Government Accountability Office, n.d.) These protests are submitted when parties believe that contracts have been unfairly or unlawfully awarded. Therefore, if a sole-source contract has been protested, private industry believes the contract could be competitively sourced. However, NASA found that contracts issued to FFRDCs are rarely protested. While the 2017 government-wide contract protest rate was 17%, NASA sustained a five-year rate of 9% and FFRDCs maintained a rate even lower (NASA, 2018b). Additionally, a sharp rise in Department of Defense bid protests over the last seven to twelve years has been found to increase the appeal of utilizing sole-source FFRDC contracting (Defense Business Board, 2017).

However, FFRDCs frequently issue mission-supporting subcontracts that are not legally subject to protest. Thus, it is difficult to differentiate between the ability to competitively offer these FFRDC-awarded contracts and industry's desire to participate in such competitions. Similarly, the findings of the Defense Business Board are difficult to attribute to the Department of Defense's intent to reduce its time to acquisition and the risk associated with assessing highly technical solutions in the face of a steady decline in its technically-capable workforce or its desire to simply avoid the resulting disadvantages of competitive contract bidding. Despite the shortcomings of this analysis and the need for more substantial and empirical research, the reality remains that due to higher salary expenses, FFRDCs are proportionately more expensive than government owned and operated R&D organizations. The debate over reducing the costs of FFRDCs through increased use of competitive contracting exists wholly as a function of this high cost and has, itself, consumed additional government resources.

The second primary disadvantage is that the independent management and operating structure of FFRDCs may lead to issues in accountability. Naturally, there are arguments on both sides of the issue of agency oversight of FFRDCs. There is concern that greater oversight can be draining to the sponsoring agencies and constraining to the FFRDC (Gallo, 2016) but there has also been Congressional concern regarding several agencies' ineffective oversight. This concern stems in part, from several high-profile incidents such as the loss of two computer hard drives, the mishandling of classified information, and the partial blinding of a student at the Los Alamos National Laboratory (Struglinski, 2003; O'Driscoll, 2003; Gallo, 2016). Several other instances of insufficient agency oversight have also been documented. In 2015, the GAO conducted a study on behalf of the House Subcommittee on Oversight and Investigations in the Committee on Veteran's Affairs found that the Department of Veteran's Affairs, which obligated approximately $244 million to FFRDCs, had incomplete authority to review its FFRDC's contractual arrangements with outside parties (2015). Another GAO study found similar barriers to effective oversight in the Departments of Defense, Energy, Health and Human Services, and Homeland Security (2008).

There are several approaches that sponsoring agencies use to conduct oversight of FFRDCs. First, agencies review and approve the work assigned to the FFRDCs to ensure that it is consistent with the scope, purpose, and capacity of the FFRDC. Second, agencies conduct financial audits and performance reviews of internal controls. Third, as stipulated in the FAR, agencies must conduct a comprehensive review of the FFRDC before renewing its contract (GAO, 2008). Other contractual mechanisms may allow agencies to enact corrective actions and punitive restrictions on FFRDCs should they fail to meet obligations, although some argue that these failures should not result in increased regulations over all FFRDCs (Stepp, Pool, Loris, & Spencer, 2013; Gallo, 2016).

In general, two thought paradigms exist regarding the government's role in exercising its oversight responsibilities; an entrepreneurial approach and the public law approach. Those favoring the entrepreneurial approach to public management value organizational and managerial flexibility and using numerical performance measures. Those favoring the public law approach argue that the purpose of agency oversight is to implement the laws of Congress, not to maximize performance, and therefore prefer a democratic practice of accountability over efficiency maximization (Kosar, 2011).

Within hybrid organizations such as FFRDCs, where funding and oversight is provided by the government and operation and management duties are conducted by the private sector, these two schools of thought are at odds. The oversight of FFRDCs is mandated in the FAR to be conducted by the sponsoring agencies, thus performing the democratic governance function, while the private FFRDC operators strive for efficiency and outcome performance. In this environment, there exists a strong propensity for conflict. Surveys indicate that FFRDC employees have indeed experienced conflicting oversight by Federal agencies (Howieson, et al., 2013). However, while each agency sponsoring an FFRDC is subject to the same federal laws, agencies often develop their own processes and procedures for conducting their oversight duties. While these differences are generally insignificant, threats to effective evaluation can be overcome by sharing knowledge and best practices between agencies (Government Accountability Office, 2008).

It has been suggested that an effective method of agency oversight includes reducing the level of scrutiny of detailed technical and administrative functions while expecting a high standard of transparency from FFRDCs. Cited as an example of this model is the NASA Jet Propulsion Laboratory which has 30 federal employees compared to Lawrence Livermore National Laboratory which has 130 federal employees, despite the organizations' similar budget sizes (Miller, 2012; Howieson, Clavin, & Sedenberg, 2013; The Commission to Review the Effectiveness of the National Energry Laboratories, 2015b). Harkening back to the issue of competing FFRDC contracts, a 2003 report found that competition creates discipline and prompts quality performance that oversight alone cannot inspire (U.S. Department of Energy Blue Ribbon Commission on the Use of Competitive Procedures for the Department of Energy Labs, 2003).

Partially due to ineffective oversight and competition with the private sector, the diversification of FFRDC research activities or partners, called "mission creep," becomes another concern of Congress. Whether this mission creep develops out of a loosely defined FFRDC mission statement or an FFRDC's desire or being compelled to compete with the private sector, allowing an FFRDC to expand its operations into a new field or take on new clients is contradictory to the stated purpose of an FFRDC (Gallo, 2016). If an FFRDC is properly established according to the regulations in the FAR, there should be no uncertainty as to the organization's mission and purpose. The sponsoring agency must clearly identify its R&D needs and fully explain the agency's and private industry's capability gap in providing the service. Mission creep rising from poorly defined mission statements is entirely the result of poor oversight by both Congress and the sponsoring agency. Similarly, if mission creep develops because the FFRDC is actively seeking to expand its portfolio with external partners or if the advocates of increased competition drive this behavior, the poor oversight of the sponsoring agency is to blame. Mission creep can reduce the impact of an FFRDC's contractual output as it diverts resources to the additional work.

Several methods are used by agencies to mitigate mission creep in their FFRDCs. The Department of Energy, for example, has placed a cap on the amount of work its FFRDCs can perform for other agencies in the amount of 20% above the FFRDC's operating budget. If the work is estimated higher, a comprehensive agency review of the FFRDC's ability to effectively continue its contractual obligations and agency approval is required before the work can begin (Task Force on Alternative Futures for the Department of Energy National Laboratories, 1995). Congress has also placed limits on the ability of the Department of Defense to establish new FFRDCs and dictated annual limits on the amount of Staff Years of Technical Effort (STE) that DOD FFRDCs can use in its work for the agency (Government Accountability Office, 2008; Gallo, 2016). By limiting the FFRDC's allowable working hours, the goal is to force it to prioritize work for the agency over competing alternatives. However, the GAO has identified gaps in each agency's oversight duties despite these measures (GAO, 2008; 2015), illuminating continued Congressional concerns over inadequacies in FFRDC oversight and accountability.

Barriers to Implementation

Many FFRDCs have been terminated and some, such as the Applied Physics Laboratory, have transitioned to the UARC model (Hruby, et al., 2011). However, there is no precedent for converting a government owned and operated R&D facility to an FFRDC. There are some examples of management changes within FFRDCs and some qualitative evaluations of transitioning federal laboratory governance models that highlight the negative effects on the workforce stemming from such a conversion. Transitioning to an FFRDC would require terminating the majority of the center's workforce leading to high rates of demoralization and loss of institutional knowledge (non-attributional primary source interviews at OMB and NASA). NASA would likely require in the foundational management and operation (M&O) contract that the FFRDC operator first extend employment opportunities to the displaced NASA employees. However, given NASA's aging workforce, it is believed that many workers would prefer to accept their terminations, collect their severance pay, and retire.

Not only would eliminating these civil service positions and offering contract buy-outs, severance pay, and early retirement be prohibitively expensive, eliminating civil service positions is not an easy legal undertaking. The process is laden with legal procedures and fraught with expensive ramifications should it fail to be fully followed. Requirements during a workforce restructuring include offering voluntary separation incentive payments, voluntary early retirement, and career transition assistance programs. Each of these options must be offered to federal employees before the process of layoffs can begin (Office of Personnel Management, n.d.). The government may be sued not only for activities such as discrimination and retaliation for whistleblowing, but also for ignoring any of the applicable civil service laws and regulations (U.S. Merit System Protection Board, 2015). Given a reduction in force of the magnitude represented by eliminating a NASA field center, it is reasonably expected that several law suits would ensue. Regardless of how NASA might fare in these decisions, the litigation expenses alone could become an unacceptable burden to the Agency.

On a large scale, it has been observed that a government-wide transition of federal laboratory governance structures from one form to another is neither advisable nor warranted (Howieson, Clavin, & Sedenberg, 2013). While incorporating positive attributes of various governance models into one another may provide some operational benefits, it has also been observed that “even management changes that do not alter the basic governance concept can be disruptive” (Howieson, Clavin, & Sedenberg, 2013). A National Research Council study of the National Nuclear Security Administration’s laboratories showed that the transition from an FFRDC run by a nonprofit to an FFRDC run by a consortium, inclusive of nonprofits, led to staff frustrations, an increase in technical staff turnover, and increased costs of the two contracts by approximately $200 million per year stemming from increased management fees, changes in healthcare and pension benefits, and changes in state tax obligations (National Research Council, 2012; Howieson, Clavin, & Sedenberg, 2013). Considering the constrained NASA budget as already discussed, the expected financial burdens of a governance model change in NASA field centers, specifically the upfront costs associated with a reduction in force followed by the sustained increase in compensation, are likely prohibitively expensive.

This barrier becomes even more salient when considering NASA's historic challenges in meeting cost, schedule, and performance goals. Despite the Agency's record of successful missions and revolutionary developments, it also has failed to meet its cost, schedule, and performance goals for many of these projects. For example, the Hubble Space Telescope was originally projected to cost $200 million and be complete by 1983, when it was actually completed and launched in 1990 at a cost of approximately $1.2 billion. Similarly, the James Webb Space Telescope was projected to cost $2.6 billion and launch in 2014 but has already exceeded $8 billion in costs with a launch date extended into 2020 (NASA Office of Inspector General, 2019). The *SLS* is another high-profile case of NASA's failure to deliver projects within budget and on schedule. Specifically, the NASA Office of Inspector General attributes these cost overruns and schedule delays in NASA's inadequate oversight and contract management practices (2018). Furthermore, the GAO has listed NASA on its "High Risk List" since 1990 over persistent cost and schedule overruns (U.S. Government Accountability Office, 2019). Each of these projects involved large-scale contracting and acquisition activities. The consistent failure of NASA to control these activities provides further context for the theory that FFRDC conversions of field centers will result in unwieldy cost increases.

Additionally, NASA identified five top risks associated with converting a field center to an FFRDC. These top five risks were selected based on potential schedule and risk impacts. Risk from technical and research areas of focus is ranked as the top risk due to a high probability of occurring and its high impact on both schedule and cost. NASA's explanation of this risk factor points to the unique purpose and mission of an FFRDC and the accompanying unforeseen obstacles of cutting-edge R&D (NASA, 2018b). However, given NASA's existing role in developing specialized and unique technologies, this risk assessment seems to inaccurately present this risk factor as a differentiating element of the FFRDC model.

The second most impactful risk NASA identified is the risk of delays due to external factors. Citing legislation and funding processes outside of NASA's control (NASA, 2018b), the Agency again seems to incorrectly attribute this risk to the FFRDC conversion as a differentiating factor. As previously discussed, NASA already faces a tumultuous political environment and uncertainty in the annual appropriations process. The NASA report fails to explain how the conversion to an FFRDC would result in any increase in this risk. The remaining three risks listed by NASA are of similar consequence. That is, reflective not of new risks associated with an FFRDC conversion, but rather the continuity of risk currently assumed in NASA's operations.

However, politics is the most powerful barrier to converting NASA field centers to FFRDCs. Congress generally takes an incrementalism approach to legislation. For example, although the unmanned aerial systems (UAS) market is rapidly propagating through all sectors of the world economy, Congress has been hesitant to mandate new rules and regulations governing both the development of safe UAS infrastructure and the establishing of safety measures to protect critical assets and national security operations against hostile or errant UAS. Absent a highly visible disaster demanding of immediate and decisive action, Congress is accustomed to slowly implementing innovative legislation. Given Congress' generally slow pace, it is unlikely that converting a civil service agency center to an FFRDC for the first time will happen.

Furthermore, the impetus to convert NASA field centers to FFRDCs has not been demonstrated in terms of Congress' values and objectives as discussed previously. This conversion would directly eliminate federal jobs from the states and districts of legislators, which is a direct assault against their primary values and objectives of creating and protecting jobs. To ask a legislator to vote for the conversion of a field center in their district is to ask them to vote for removing reliable, high-paying, and rewarding jobs from their constituents in order to implement a risky and untested strategy with no demonstrable advantages over the existing system. This aspect is arguably the greatest obstacle to transitioning NASA field centers to FFRDCs. Unless an important individual on a powerful committee is convinced of the efficacy of such a plan, most likely by a comprehensive analysis which provides empirical evidence that the conversion would most certainly result in substantial economic development and secondary job creation, the plan has nearly no chance of success.

Summary

NASA is continually being asked to do more with less. Since the precipitous decline in its budget following the *Apollo* program build-up of the mid-1960s, NASA's budget has remained relatively flat in constant dollars although its share of the federal budget has been in steady decline. Despite this relative budgetary decline, the Agency itself has continued to grow, adding several mission directorates, field centers, and undertaking several large-scale projects like the Space Shuttle, the International Space Station, and the Space Launch System. This discrepancy exemplifies the apparent mismatch between the Agency's mission statement and its resources.

Furthermore, NASA's organizational structure and governance models have undergone relatively little development or change since the Agency's inception. With the primary changes being a shuffling of mission directorate authorities over the field centers and the creation, closure, and relocation of administrative offices within the executive level, NASA has displayed relatively little innovation regarding its governance and management structures. Combined with several high-impact catastrophes, the Agency faces consistent scrutiny from the legislative and executive branches which often have competing values, priorities, and expectations of NASA.

The executive branch's values and expectations of efficiency have occasionally led to the recommendation that NASA adopt the FFRDC model for its field centers. The perceived benefits of this model include increased flexibility in workforce management, agility and responsiveness to changing economic and political influences over federal R&D needs, and the ability to attract and retain higher caliber employees leading to increased innovation. While these benefits exist, there are additional burdens and disadvantages of the FFRDC model including increased costs of operation, unfair competition with the private sector, and mission creep resulting from reduced accountability and government oversight.

While there are several feasible implementation variations of the FFRDC model, the disadvantages of and barriers to converting field centers to FFRDCs in any of these alternatives are so great as to prohibit such a transition. Such a restructuring of the NASA field centers carries excessively high costs to implement and maintain. Considering the costs, a lack of evidence that the conversion would be beneficial to the economy at large, and that converting a federally owned and operated R&D center to an FFRDC has never been undertaken, Congress is unreceptive to such a proposal. Despite the executive branch's insistence that the conversion would increase government efficiency and productivity, NASA leadership is similarly circumspect in their evaluation of the proposition. The only variation that has any level of support outside of the executive branch is the option of establishing new FFRDCs for specialized, emerging long-term missions.

Recommendations

Based on this analysis, several paths forward are recommended. First, as referenced in NASA's response study to OMB, it is agreed that the agility and responsiveness issues in the larger system of civil service human resources should be addressed. The benefits packages and job security provided in the civil service are attractive but appear to be increasingly perceived as less valuable by younger generations. Perhaps the full cost of accounting to communicate the true monetary equivalent value of civil service jobs is not being adequately leveraged in attracting top talent. The cumbersome system of employee performance evaluation and due process is certainly restricting to agility and innovation, and the government's time to hire ratios are abysmally high compared to the private sector. Facing an increasingly aging workforce and lagging in the recruitment of young professional talent, ***it is recommended that NASA and other interested parties advocate for the execution of studies to determine the best methods for instituting civil service reforms aimed at increasing speed and agility while maintaining the important protections currently embedded in the system***.

Second, while the discussion of risk factors is largely absent in this paper, as recently noted by Daniel Dumbacher of the American Institute of Aeronautics and Astronautics (AIAA), in the wake of the Challenger and Columbia disasters NASA has become an increasingly riskaverse agency; to the extent that innovation and advancements have been stifled (AIAA, 2019). It is therefore ***recommended that NASA and other interested parties conduct risk assessments of NASA's critical human spaceflight missions, explore the methods, including the possibility of using FFRDCs, by which the Agency can mitigate risk, and develop the methods that allow NASA to pursue its programs without such restrictive and inhibitive policies and procedures***.

Third, the establishment of new FFRDCs for the purpose of providing specialized capabilities in support of emerging Agency needs may be advantageous and is the only currently feasible avenue for NASA to increase its use of the FFRDC model. Examples of specialized, long-term emerging needs include developing in-situ resource utilization practices and infrastructure and developing permanent lunar facilities and support systems such as the planned Lunar Orbital Platform-Gateway. If new FFRDCs are to be established, it is essential that buy-in and support be secured from the critical stakeholders, such as private industry, the National Space Council, and most importantly, Congress. Congress will require assurances that the new FFRDC is truly necessary to achieving NASA's mission if it is to appropriate the additional funds needed to establish the FFRDC. These costs can best be justified by ***conducting a study on the full lifetime cost of employment in the civil service, a metric which is not currently reflected in agency financial statements or considered in Congressional appropriations deliberations***. Industry will require that any new FFRDC be free from unfair competitive advantage. This can be accomplished by ***demonstrating that the FFRDC could be sized so that it does not contain the internal capacity to complete all its objectives without issuing mission-critical subcontracts to private industry***.

Fourth, if the establishing of a new FFRDC were to be authorized, ***it is recommended that the FFRDC be located within the same geographical region as the field center with which its purpose most closely aligns,*** thus creating quasi-experimental conditions for ***future economic impact analysis***. If new FFRDCs can then be empirically shown to improve regional economic conditions in addition to increasing agency efficiency and innovation, the prospect of converting NASA field centers to FFRDCs could gain traction in Congress, with sponsorship and advocacy from one or several influential legislators.

Finally, as the primary obstacle to transitioning NASA field centers to FFRDCs and the only remaining basis of analysis yet to be appropriately or effectively conducted, ***it is recommended that an empirical economic study of the regional economic impacts of an FFRDC be conducted***. Regardless of NASA's path forward regarding FFRDCs, this study must be conducted and peer-reviewed. Otherwise, the arguments will never have a chance of being genuinely considered by the parties with the true decision-making power.

NASA's history is full of accomplishments and achievements that have captured the global imagination. A lasting testament to the creativity, ingenuity, and perseverance of the human spirit, NASA will remain an inspiration to innovators, leaders, and pioneers for generations to come. Whether it endures as a nexus for visionary progress and exploration or recedes into the realm of memory and legend will be determined by the actions of leaders today. Hopefully, this investigation, in some way, can enhance the conversation and help illuminate the path to continued greatness.

References

American Council on Education. (n.d.). *A Brief Guide to the Federal Budget and Appropriations Process*. Retrieved from American Council on Education: https://www.acenet.edu/news-room/Pages/A-Brief-Guide-to-the-Federal-Budget-and-Appropriations-Process.aspx

American Institute of Aeronautics and Astronautics. (2019, March 26). *Human Space Exploration - It's Worth the Risk, Written Statement of Mr. Daniel L. Dumbacher - Executive Director of the American Institute of Aeronautics and Astronautics, Before the National Spaced Council*. Reston, VA.

Berger, E. (2017, June 30). *Trump to sign executive order creating a national space council: The council is needed to modernize the nation's approach to spaceflight.* Retrieved from Ars Technica: https://arstechnica.com/science/2017/06/trump-to-sign-executive-order-creating-a-national-space-council/

Broad, W. J. (2014, March 15). *Billionaires With Big Ideas Are Privatising American Science.* Retrieved from The New York Times: https://www.nytimes.com/2014/03/16/science/billionaires-with-big-ideas-are-privatizing-american-science.html

Bureau of Labor Statistics. (n.d.). *Consumer Price Index*. Retrieved from Bureau of Labor Statistics: https://www.bls.gov/cpi/tables/historical-cpi-u-201709.pdf

Center for Responsive Politics. (2019, April 5). *Defense Aerospace*. Retrieved from OpenSecrets.org: https://www.opensecrets.org/industries/indus.php?cycle=2018&ind=D01

Committee on NASA's Strategic Direction. (2012). *NASA's Strategic Direction and the Need for a National Consensu.* Washington, D.C.: The National Academy of Sciences.

Creech, S. D. (2014). *NASA's Space Launch System: An Enabling Capability for Discovery.* Washington, D.C.: NASA.

Defense Business Board. (2017). *Future Models for Federally Funded Research and Development Center Contracts: Recommendations on managing federally funded research and development center contracts.* Washington, D.C.: Defense Business Board.

Donahue, A. K., & O'Leary, R. (2012). Do Shocks Change Organizations? The Case of NASA. *Journal of Public Administration Research & Theory*, 395-425.

Eden, C., & Ackermann, F. (1998). *Making Strategy: The Journey of Strategic Management.* Thousand Oaks: Sage Publications.

Ewalt, D. (2016, March 8). *The World's Most Innovative Research Institutions.* Retrieved from Reuters: https://www.reuters.com/article/us-innovation-rankings/the-worlds-most-innovative-research-institutions-idUSKCN0WA2A5

Federal Acquisition Regulations. (2005). *35.017-7(a).*

Foust, J. (2018, May 8). *NASA missions press ahead despite budget uncertainty*. Retrieved from SpaceNews: https://spacenews.com/nasa-missions-press-ahead-despite-budget-uncertainty/

Foust, J. (2019, March 11). *NASA budget proposal targets SLS*. Retrieved from SpaceNews: https://spacenews.com/nasa-budget-proposal-targets-sls/

Gallo, M. E. (2016). *Federally Funded Research and Development Centers (FFRDCs): Background and Issues for Congress.* Washington, D.C.: Congressional Research Service.

Government Accountability Office. (2008). *Federal Research: Opportunities Exist to Improve the Management and Oversight of Federally Funded Research and Development Centers.* Washington, D.C.: GAO.

Government Accountability Office. (2015). *Report to the Chairman, Subcommittee on Oversight and Investigations, COmmittee on Veterans' Affairs, House of Representatives, Veterans Affairs Contracting: Improved Oversight Needed for Certain Contractual Arrangements.* Washington, D.C.: Government Accountability Office.

Haeder, S. F., & Yackee, S. W. (2015). Influence and the Administrative Process: Lobbying the U.S. President's Office of Management and Budget. *American Political Science Review*, 507-522.

Heracleous, L., Terrier, D., & Gonzales, S. (2018, April 23). *The Reinvention of NASA.* Retrieved from Harvard Business Review: https://hbr.org/2018/04/the-reinvention-of-nasa

Howieson, S. V., Clavin, C. T., & Sedenberg, E. M. (2013). *Federal Security Laboratory Governance Panels: Observations and Recommendations.* Washington, D.C.: Institute for Defense Analysis.

Howieson, S. V., Peña, V., Shipp, S. S., Koopman, K. A., Scott, J. A., & Clavin, C. T. (2013). *A Study of Facilities and Infrastructure Planning, Prioritization, and Assessment at Federal Security Laboratories (Revised).* Washington, D.C.: Insitute for Defense Analysis.

Hruby, J. M., Manley, D. K., Stoltz, R. E., Webb, E. K., & Woodard, J. B. (2011, Spring). The Evolution of Federally Funded Research & Development Centers. *Public Interest Report, 64*(1), pp. 24-30.

Kaplan, S. (2017, June 30). *President Trump Relaunches the National Space Council*. Retrieved from The Washington Post: https://www.washingtonpost.com/news/speaking-of-science/wp/2017/06/30/trump-relaunches-the-national-space-council/?utm_term=.8304a7522deb

King, L. (2013, May 10). *Political wrangling pulls NASA in different directions*. Retrieved from USA Today: https://www.usatoday.com/story/news/politics/2013/05/10/congress-and-administration-at-odds-on-nasa-mission/2151559/

Kosar, K. R. (2011). *The Quasi Government: Hybrid Organizations with both Government and Private Sector Legal Characteristics.* Washington, D.C.: Congressional Research Service.

Lal, B. (2018). *Threats to U.S. Competitiveness in Space: Oral and Written Statements for the 21 February 2018 Meeting of the U.S. National Space Council.* Washington, D.C.: IDA Science & Technology Policy Institute.

Lee, R., Johnson, R. W., & Joyce, P. G. (2013). *Public Budgeting Systems.* Burlington: Jones & Bartlett Learning.

Miller, G. H. (2012). *Governance, Oversight, and Management of the Nuclear Security Effectiveness in an Age of Austerity.* statement of George H. Miller, Lawrence Livermore National Laboratory, before the House Armed Services Committee, Strategic Forces Subcommittee, 112th Congress, 2nd session.

MITRE. (2015). *FFRDCs - A Primer: Federally Funded Research and Development Centers in the 21st Century.* McLean, VA: The MITRE Corporation.

NAC Institutional Committee. (2017). *NAC Institutional Committee Meeting.* Washington, D.C.: NASA.

NASA. (2017a). *2017 Economic Impact Report: NASA Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR).* Moffett Field: NASA Ames Research Center.

NASA. (2017b). *Annual Procurement Report: Fiscal Year 2017.* Washington, D.C.: NASA Office of Procurement.

NASA. (2018a). *FY2018 Agency Financial Report.* Washington, D.C.: NASA.

NASA. (2018b). *Reshaping American Government in the 21st Century: Improving NASA's Agility through Increased Use of Federally Funded Research and Development Centers - NASA Response.* Washington, D.C.: NASA.

NASA Office of Inspector General. (2018). *NASA's Management of the Space Launch System Stages Contract.* Washington, D.C.: NASA OIG.

NASA Office of Inspector General. (2019). *NASA Cost and Schedule Overruns: Acquisistions and Program Management Challenges.* Washington, D.C.: NASA OIG.

NASA Office of Management. (1985). *The Evolution of the NASA Organization.* Washington, D.C.

National Academy of Sciences. (2011). *Vision and Voyages for Planetary Science in the Decade 2013-2022.* Washington, D.C.: The National Academies Press.

National Research Council. (2012). *Managing for High-Quality Science and Engineering at the NNSA National Security Laboratories.* Washington, D.C.: The National Academies Press.

National Science Foundation. (2018). *Master Government List of Federally Funded R&D Centers (FFRDCs) - March 2018.* Washington, D.C.: National Science Foundation/National Center for Science and Engineering Statistics.

O'Driscoll, M. (2003, May 1). Nuclear Safety: Lawmakers Seek GAO Help in Solving Los Alamost Problems. *Greewire*.

Office of Management and Budget. (2018). *Delivering Government Solutions in the 21st Century: Reform Plan and Reorganization Recommendations.* Washington, D.C.: OMB.

Office of Management and Budget. (n.d.). *Historical Tables*. Retrieved from Office of Management and Budet: https://www.whitehouse.gov/omb/historical-tables/

Office of Personnel Management. (n.d.). *Managing Federal Employees' Performance Issues or Misconduct.* Washington, D.C.: OPM.

Office of Personnel Management. (n.d.). *Workforce Restructuring*. Retrieved from Office Of Personnel Management: https://www.opm.gov/policy-data-oversight/workforce-restructuring/

Office of Research Services. (n.d.). *U.S. Research Insitutions Received OVer $2.3 Billion in Private Funding for Basic Science in 2017.* Retrieved from Loyola University Chicago Office of Research Services: https://www.luc.edu/ors/homenews/usresearchinstitutionsreceivedover23billioninprivatefundingforbasicsciencein2017.shtml

Office of Science and Technology Policy. (n.d.). *Office of Science and Technology Policy*. Retrieved from The White House: https://www.whitehouse.gov/ostp/

President's Commission on Implementation of United States Space Exploration Policy. (2004). *Report of the President's Commission on Implementation of United States Space Exploration Policy: A Journey to Inspire, Innovate, and Discover.* Washington, D.C.: Government Printing Office.

Professional Services Council. (2012). *Federally Funded Research and Development Centers: A Strategic Reassessment for Budget-Constrained Times.* Arlington: Professional Services Council.

Risher, H. (2017, July 5). *The Untapped Potential of HR in Government*. Retrieved from Governing: https://www.governing.com/columns/smart-mgmt/col-untapped-potential-human-resources-workforce-management-performance.html

Rosenbloom, D. H. (2003). *Administrative Law for Public Managers.* Boulder, CO: Westview Press.

Science Philanthropy Alliance. (2018, June 7). *U.S. Research Institutions Received Over $2.3 Billion in Private Funding for Basic Science in 2017.* Retrieved from Science Philanthropy Alliance: https://www.sciencephilanthropyalliance.org/u-s-research-institutions-received-over-2-3-billion-in-private-funding-for-basic-science-in-2017-alliance-news/

Senate Committee on Commerce, Science, and Transportation. (2010). *Report of the Committee on Commerce, Science, and Transportation on S. 3729.* Washington, D.C.: U.S. Government Printing Office.

Stepp, M., Pool, S., Loris, N., & Spencer, J. (2013). *Turning the Page: Reimagining the National Labs in the 21st Century Innovation Economy.* Information Technology and Innovation Foundation, Center for American Progress, and the Heritage Foundation.

Stromberg, J. (2015, February 4). *For NASA, sending a person to Mars is simple. Dealing with Congress is hard.* Retrieved from Vox: https://www.vox.com/2015/2/4/7977685/mars-nasa-orion-sls

Struglinski, S. (2003, May 1). DOE: Abraham Announces Los Alamos Contract Will Undergo Competitive Bidding. *Greenwire*.

Task Force on Alternative Futures for the Department of Energy National Laboratories. (1995). *Alternative Futures for the Department of Energy National Laboratories.* Secretary of Energy Advisory Board.

The Commission to Review the Effectiveness of the National Energy Laboratories. (2015b). *Securing America's Future: Realizing the Potential of the Department of Energy's National Laboratories - Volume 2.* Washington, D.C.: Department of Energy.

The Commission to Review the Effectiveness of the National Energy Laboratories. (2015a). *Securing America's Future: Realizing the Potential of the Department of Energy's National Laboratories. Volume 1: Executive Report.* Washington, D.C.: U.S. Department of Energy.

Thompson, A. (2019, March 14). *NASA's Supersize Space Launch System Might Be Doomed*. Retrieved from Wired: https://www.wired.com/story/nasas-super-sized-space-launch-system-might-be-doomed/

U.S. Department of Defense. (2010). *University Affiliated Research Center (UARC) Management Plan.* Washington, D.C.: U.S. Department of Defense.

U.S. Department of Defense. (2011). *Federally Funded Research and Development Center Management Plan.* Washington, D.C.: U.S. Department of Defense.

U.S. Department of Energy. (2009). *Policy Regarding the Competition of Contracts to Manage and Operate Its National Laboratories.* Washington, D.C.: U.S. Department of Energy.

U.S. Department of Energy Blue Ribbon Commission on the Use of Competitive Procedures for the Department of Energy Labs. (2003). *Competing the Management and Operations Contracts for DOE's National Laboratories,.* Washington, D.C.: Department of Energy.

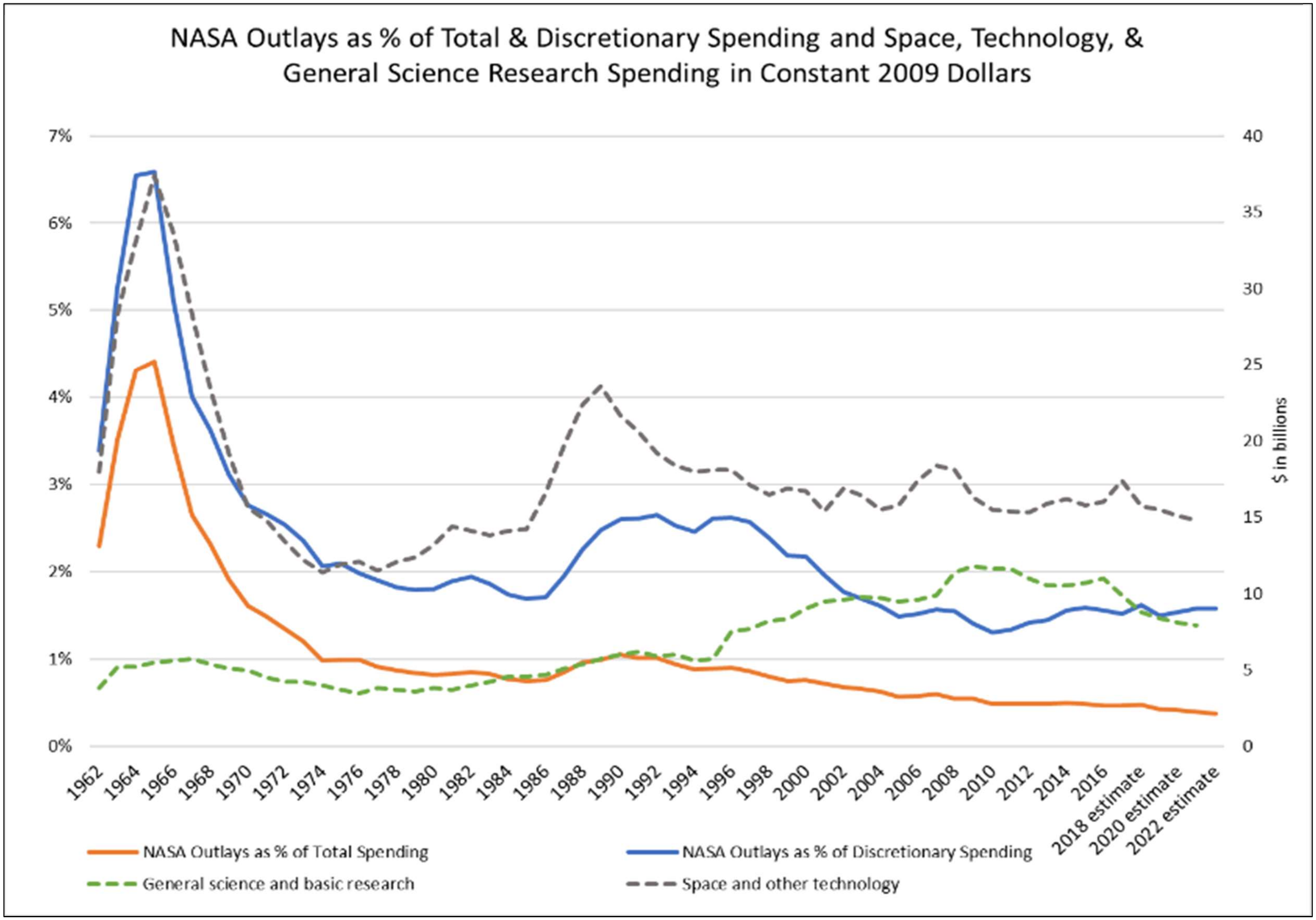
U.S. Government Accountability Office. (2019, March 26). *James Webb Space Telescope: Opportunity Nears to Provide Additional Assurance That Project Can Meet New Cost and Schedule Commitments*. Retrieved from U.S. Government Accountability Office: https://www.gao.gov/products/GAO-19-189

U.S. Government Accountability Office. (n.d.). *Bid Protests, Appropriations Law, & Other Legal Work: FAQs*. Retrieved from U.S. Government Accountability Office: https://www.gao.gov/legal/bid-protests/faqs

U.S. Merit System Protection Board. (2015). *What is Due Process in Federal Civil Service Employment?* Washington, D.C.: U.S. Merit System Protection Board.

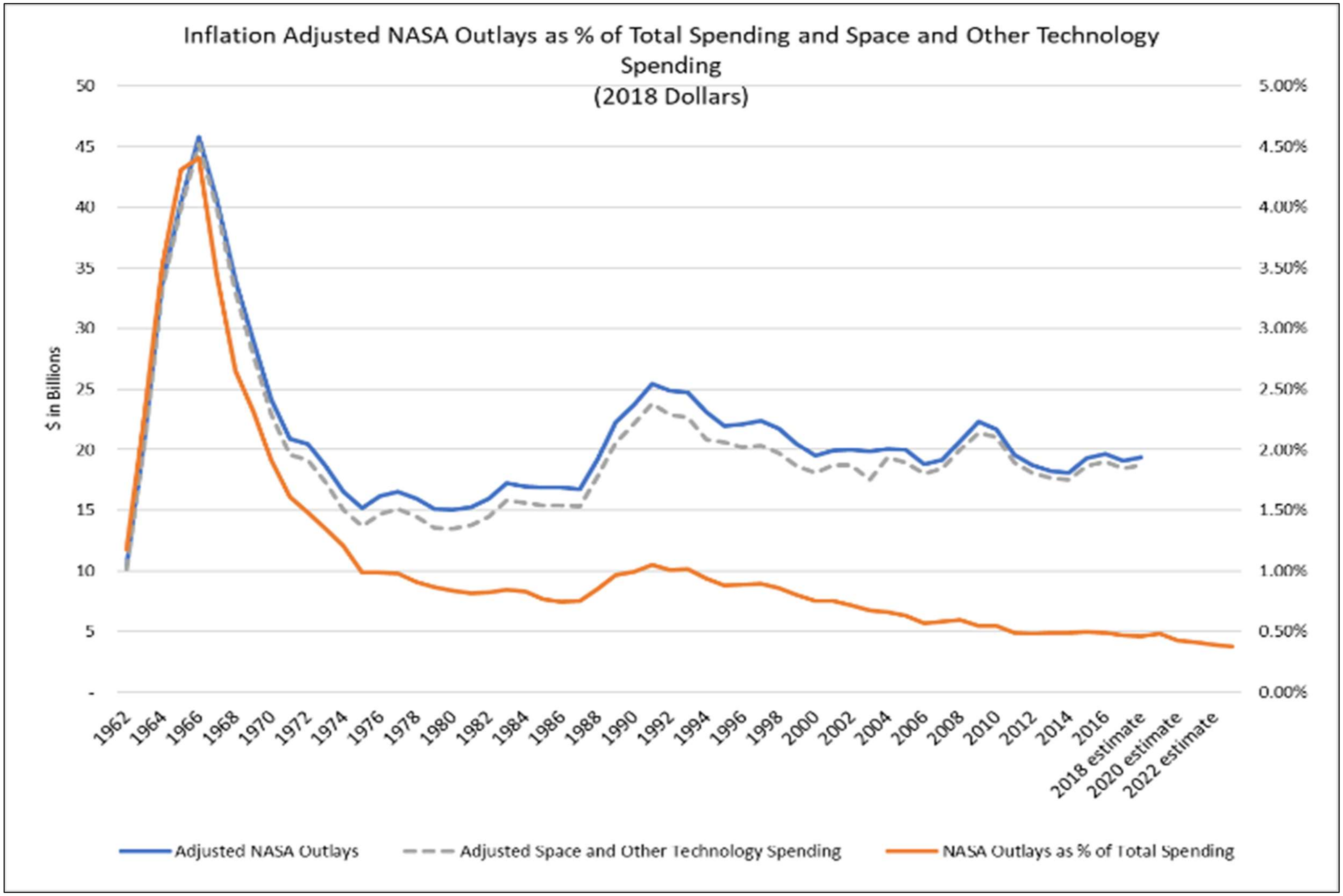
Whitson, P. A. (2019). *Statement before the House Subcommittee on Space, Science, and Technology: America in Space: Future Visions, Current Issues.* Washington, D.C.: House Committee on Science, Space, and Technology.

Figure 1



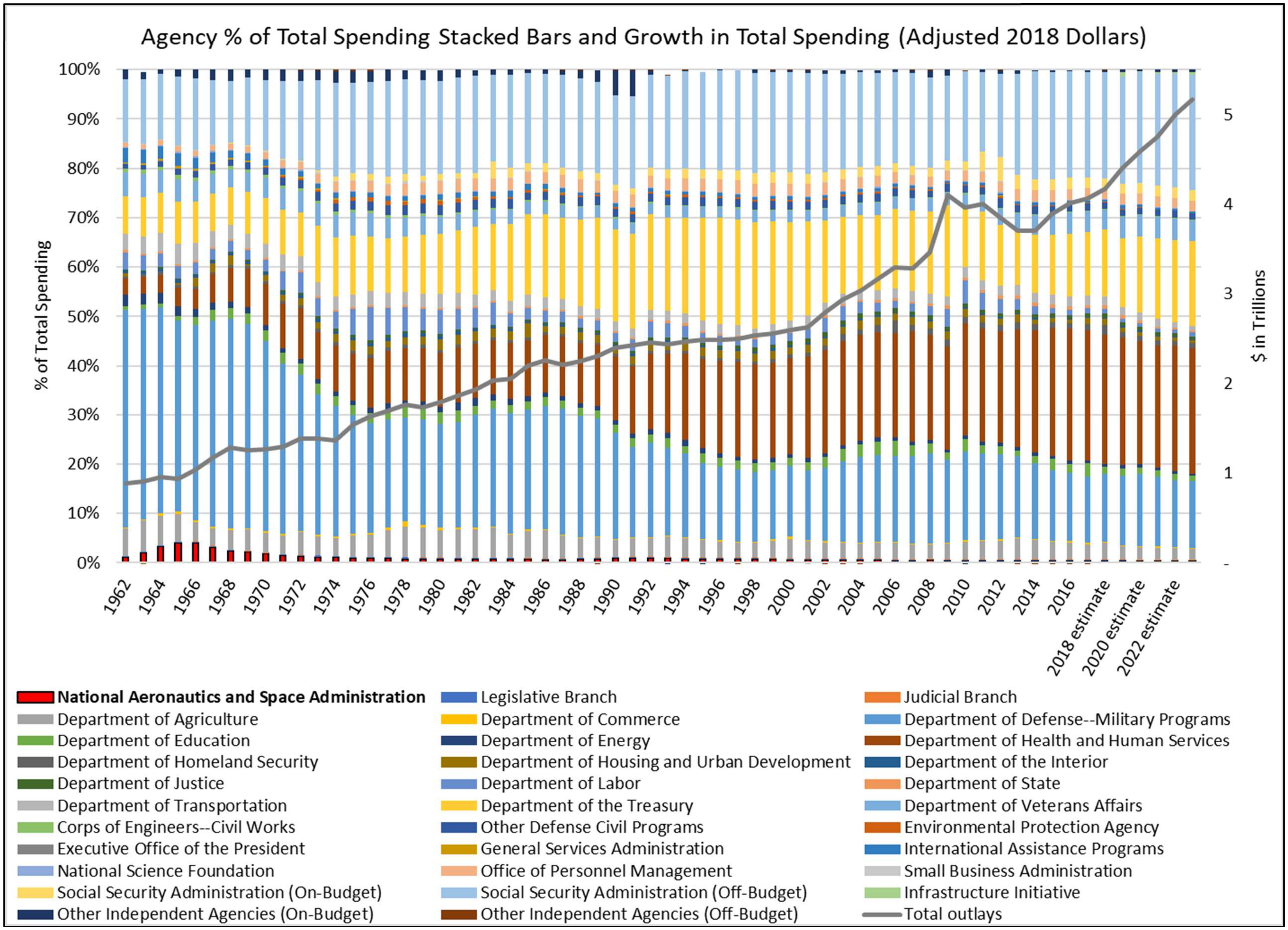
Source: OMB Historical Budget Tables

Figure 2



Source: OMB Historical Budget Tables, Bureau of Labor Statistics Historical CPI Tables

Figure 3



Source: OMB Historical Budget Tables, Bureau of Labor Statistics Historical CPI Tables

Appendix B – Power vs Interest Grid

Figure 4 - NASA Stakeholder Power vs Interest Matrix

High

Power

Low

Context Setters

***Senate Committee on Commerce, Science, and Transportation**
- Chairman Roger Wicker
- Ranking Member Maria Cantwell

***House Committee on Science, Space, and Technology**
- Chairwoman Bernice Johnson
- Ranking Member Frank Lucas

***President Trump**

***Senate and House Majority Leaders**

Players

***Senate Subcommittee on Aviation and Space**

Chairman Ted Cruz	Ranking Member Kyrsten Sinema
John Thune	Brian Schatz
Roy Blunt	Tom Udall
Jerry Moran	Gary Peters
Cory Gardner	Tammy Duckworth
Marsha Blackburn	Jon Tester
Sheley Moore Capito	Jacky Rosen
Mike Lee	

***House Subcommittee on Space and Aeronautics**

Chairwoman Kendra Horn	Ranking Member Brian Babin
Zoe Lofgren	Mo Brooks
Ami Bera	Bill Posey
Ed Perlmutter	Pete Olson
Don Beyer	Michael Waltz
Charlie Crist	
Katie Hill	
Jennifer Wexton	

***Representatives with NASA Field Centers in their Districts (if not already mentioned)**

David Trone	Marcy Kaptur
Adam Schiff	Anna Eshoo
Kevin McCarthy	Elaine Luria

***NASA Administrator Jim Brindenstine**

***Vice President Pence & National Space Council**

***Office of Management and Budget**

Crowd

***The rest of Congress**

***International Partners**
- ESA
- Roscosmos
- JAXA

***International Competitors**
- China

***Citizens**

Subjects

***Office of Science and Technology Policy**

***Contractors**

***Mission Directorate Associate Administrators**

***FFRDC/UARC Operators**

***Field Center Directors**

***Academia**

***Program & Project Managers**

***Think Tanks**

***All other NASA staff**

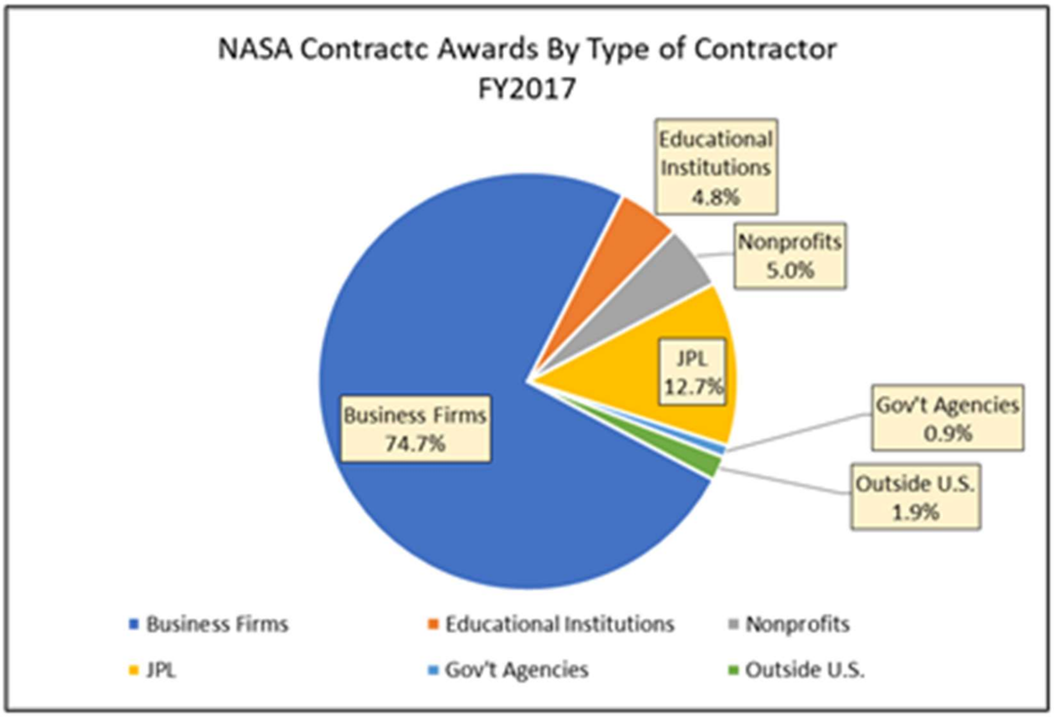
Low — High

Interest

** Stakeholder locations within quadrants do not represent the true values of their power and interest levels, but rather an approximation constrained by the space available within each quadrant

Appendix C – Procurement

Figure 5



*Source: NASA Annual Procurement Report FY2017

Table 1 - NASA Contract Awards by Type of Contractor in FY17

Category	Value (millions)	Percent of Total
Business Firms	$13,827.7	74.7%
Educational Institutions	$880.2	4.8%
Nonprofits	$924.5	5.0%
JPL	$2,352.6	12.7%
Gov't Agencies	$171.3	0.9%
Outside U.S.	$346.2	1.9%
Total	$18,502.5	100%

*Source: NASA Annual Procurement Report FY2017